Aeronautics & Space Transportation Technology: Three Pillars for Success

Three Pillars for Success

NASA's Response to Achieve the National Priorities in Aeronautics and Space Transportation

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Message from the NASA Administrator

Aviation has always been an exciting and risk-taking endeavor. With a strong partnership among industry, government, and academia, there has been an incredible history of innovation and technological breakthroughs. As we enter the 21st century, we in the aerospace community are excited about the future.

Leading the world in flight—in the air as well as in space—has a profound impact on our Nation, socially, economically, and politically. Unbelievable discoveries are right over the horizon, but to achieve them requires an ambitious view of the future and a willingness to take risks. As the Administrator of NASA, my responsibility to the American public is to ensure that NASA's work in science and technology sustains U.S. leadership in civil aeronautics and space.

My challenge to NASA's Aeronautics and Space Transportation Technology Enterprise to set bold objectives for the future is answered in the next few pages. The goals that follow are dramatic—they are pre-competitive research endeavors in long-term, high-risk, high-payoff technologies. I emphasize the NASA role in these terms because the Government must look to the future in pivotal areas that our private sector cannot afford to address due to the sheer scale, risk, and duration of the task. Industry's responsibility is to maintain their near-term competitiveness through evolutionary advancements to their products. NASA's responsibility is to provide revolutionary advancements that protect U.S. leadership for future generations. The impact of NASA's research on our national air transportation system, our national security, the environment, and our economy demonstrates a clear government role in support of the public good.

Our goals reflect national priorities for aeronautics and space as outlined by the National Science and Technology Council in a series of three aeronautics reports and in the National Space Policy. Today, more than ever, we must ensure the relevance of our national investments. The value of our work to the U.S. taxpayer is the extent to which we add to the economic well-being and security of this country. I have no doubt that both the commercial and defense sectors of U.S. industry will continue to draw benefits from our national facilities, and the tools and technologies we develop. An extensive strategic planning process, guided by the National Research Council, provided an independent validation of our program directions and emphases.

We group our goals into three areas, or "Three Pillars," which are: "Global Civil Aviation," "Revolutionary Technology Leaps," and "Access to Space." Throughout the pillars we present "technology goals" which are framed in terms of a final outcome, the anticipated benefit of NASA-developed technology, once it has been incorporated by industry. These goals will stretch the boundaries of our knowledge and capabilities. They require taking risks and performing the long-term research and development programs needed to keep the United States as the global leader in aeronautics and space.

In accomplishing these goals, we can look forward to aircraft that are compatible with our environment and fly with a near perfect safety record, using an aviation system that provides rapid, affordable, dependable service for all. I believe flying will become as convenient in our personal lives as the automobile and integral to the way we do business. Low-cost access to space will stimulate advances in science, commerce, and exploration in ways we cannot imagine today.

Taking prudent risks and looking at radical departures from the way we do business today are essential to tomorrow's survival. I am excited about the Enterprise's goals and proud to be a part of the NASA team and this important work. As Administrator, I will see to it that we pursue our goals aggressively and that the benefits of our national investments are shared by all segments of our society.

Daniel S. Goldin

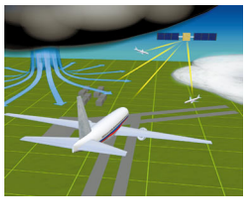
March 1997

March 1985

February 1987

August 1995

Presidential Reports on Aeronautics



Seamless integration of air travel into the fabric of society: easily accessible, easily utilized, safe, affordable travel with minimal environmental impact. Customer demands will drive air travel systems, services, and products.

Prior to 1974, large commercial transport manufacturing was the domain of the United States, with more than 90 percent of the world market share. Today over 11,000 airplanes are in commercial service worldwide, and the U.S. faces strong international competition. Aviation is of vital importance because its products are the largest positive industrial contributor to the U.S. balance of trade. Projections linked to world economic growth suggest air travel demand will triple over the next 20 years. To preserve our Nation's economic health and the welfare of the traveling public, NASA must provide high-risk technology advances for safer, cleaner, quieter, and more affordable air travel.

Safety

Our global society is highly dependent on air transportation. Great strides have been made over the last 40 years to make flying the safest of all the major modes of transportation. However, even today's low accident rate is not good enough. If air traffic triples as predicted, this rate will be totally unacceptable. The impact on domestic and international travel will have economic consequences well beyond the American transportation sector. Dramatic steps, through joint FAA, DOD, and NASA research, will assure unquestioned safety for the traveling public.

Even as more technology finds its way into the cockpit, human beings still make the critical flight decisions. Because a high percentage of accidents are related to human error, research emphasis on human-related factors will make significant contributions toward flight safety. Continued research on the complex interactions of flight crews with ground controllers, with cockpit technology, and with the aircraft will provide the insight needed to design error-tolerant systems.

New technologies for improved situational awareness will dramatically increase air system safety. A global air traffic management system to prevent collisions with other aircraft and terrain, and sensors to detect weather hazards will be major advancements. Also needed are on-board monitoring systems to predict, detect, and correct potential malfunctions, and other technologies to assure the integrity of aging aircraft.

- Enabling Technology Goal: Reduce the aircraft accident rate by a factor of five within 10 years, and by a factor of 10 within 20 years.

Environmental Compatibility

Although aircraft produce only a small fraction of the world's air pollution compared to other sources, it is in the best interest of our nation to protect the environment. The United States must demonstrate leadership in setting and meeting challenging environmental goals for aircraft. We believe there are technological solutions that will significantly reduce aircraft emissions that contribute to global warming and ozone depletion, even as travel volume increases.

In joint research ventures with industry, we are pursuing innovative engine technologies that will lead to cleaner-burning and higher-efficiency engines, providing American industry with the ability to meet increasingly strict international standards.

- Enabling Technology Goal: Reduce emissions of future aircraft by a factor of three within 10 years, and by a factor of five within 20 years.

Aircraft noise is the other area where future environmental regulations will challenge us to provide advanced technology concepts and innovations. Previous NASA noise-reduction research is now embodied in new aircraft entering the fleet, and in modifications to existing aircraft. Can we go further and create aircraft that are so quiet that the predominant noise at airports comes from cars and buses? NASA research directed at engine configurations, lighter materials, and lower airframe noise will provide the answers.

- Enabling Technology Goal: Reduce the perceived noise levels of future aircraft by a factor of two from today's subsonic aircraft within 10 years, and by a factor of four within 20 years.*

Both of these environmental goals have the requirement to be achieved without affecting safety or affordability

Affordable Air Travel

Airlines and businesses lose billions of dollars annually from delays and lost productivity due to weather and congestion in our severely constrained airspace system.

In the next two decades 12,000 new commercial airplanes will be required to accommodate the projected growth in travel and to replace older aircraft. Joint NASA and FAA research into unrestricted flight routing, or "Free Flight," will allow more aircraft to safely share airspace under adverse weather conditions. Free Flight will improve air travel affordability by increasing flight dependability and reducing delays, even at the busiest airports. If new technologies could shave just four minutes off every commercial flight today, it would provide additional capacity equivalent to another major airline.

- Enabling Technology Goal: While maintaining safety, triple the aviation system throughput, in all weather conditions, within 10 years.

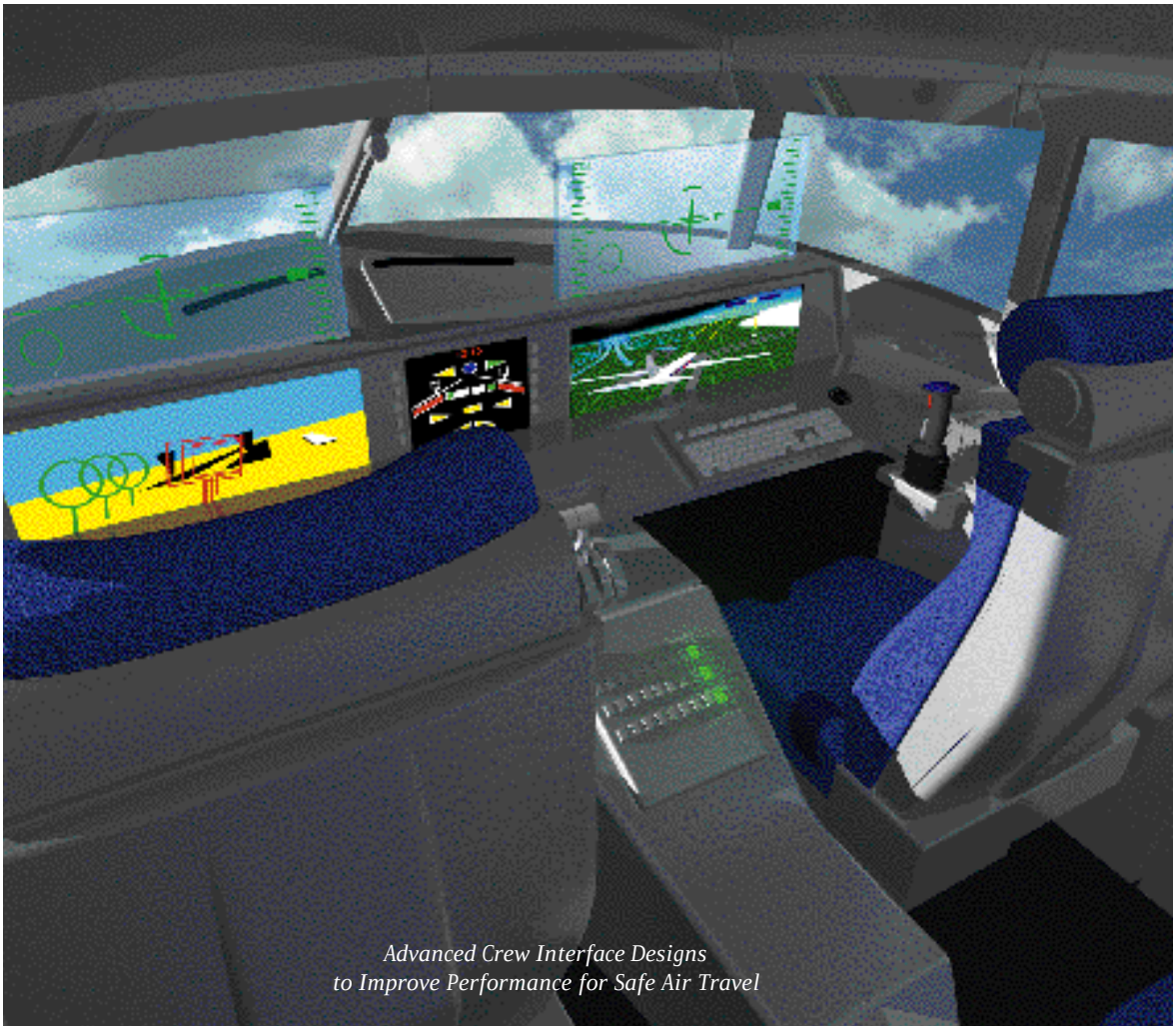
For the aircraft manufacturers, a major challenge is to reverse the trend of increasing aircraft ownership and operating costs. Dramatic time and cost savings in development, production, and certification are needed.

NASA's test facilities and core expertise in materials, structures, aerodynamics, propulsion, analytical methods, and computational tools will be key elements in helping to revolutionize aircraft design and manufacturing. NASA's research efforts will focus on innovative design techniques and structural concepts to enable the U.S. aviation industry to significantly advance today's state of the art for aircraft and engines.

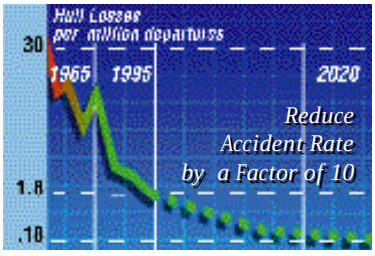
Only by increasing air system capacity and reducing aircraft costs will air travel become more affordable.

- Enabling Technology Goal: Reduce the cost of air travel by 25% within 10 years, and by 50% within 20 years.

* A factor of 2 reduction in perceived noise is about 10 EPNdB and 4 is 20 EPNdB.

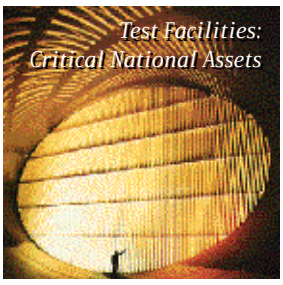


Advanced Crew Interface Designs
to Improve Performance for Safe Air Travel

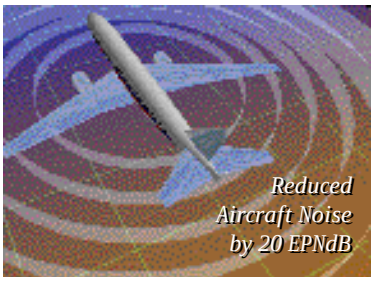


Reduce
Accident Rate
by a Factor of 10

Tiltrotor for Urban Accessibility



Test Facilities:
Critical National Assets



Reduced
Aircraft Noise
by 20 EPNdB

Research to revolutionize air travel: environmentally friendly transoceanic supersonic flights; technology to dramatically improve small aircraft designs, engines, and overall affordability.

NASA's charter is to explore high-risk technology areas that can revolutionize air travel and create new markets for U.S. industry. The technology challenges for NASA include: eliminating the barriers to affordable supersonic travel, expanding general aviation, and accelerating the application of technology advances.

Barriers to High-Speed Travel

To assure our nation's long-term aeronautical leadership we must look to a future of value-based competition. Simply put, the U.S. must bring to market products that dramatically benefit the traveling public at affordable levels and do so without harming our environment.

Since the sound barrier was broken 50 years ago, most modern fighter aircraft have the capability to fly faster than the speed of sound. However, today's supersonic engines cannot meet international standards for a clean and quiet community. To bring this capability to commercial air travel, a number of technical barriers must be overcome.

Among NASA's technology goals for removing the environmental and economic barriers are: (1) quiet supersonic engines able to meet subsonic aircraft noise standards; (2) clean supersonic engines with emissions 75 percent lower than today's aircraft; and (3) low-cost materials and structural concepts for affordability. The result will revolutionize overseas air travel.

- Enabling Technology Goal: Reduce the travel time to the Far East and Europe by 50 percent within 20 years, and do so at today's subsonic ticket prices.

General Aviation Revitalization

The general aviation segment of air travel, which includes privately owned aircraft, has tremendous potential for growth if a number of technical issues are solved. At its peak in 1978, the U.S. general aviation industry delivered 17,811 aircraft. In 1996, the number of aircraft delivered had fallen to 1,132 Along with a critical tort reform in 1994, the technology innovations anticipated for general aviation will revitalize this industry.

In 1994, NASA embarked on a unique government-industry-university partnership to make dramatic improvements in future general aviation aircraft, engines, and flight training for the next generation of four-to-six-seat, single-engine light planes. This technology revolution will feature fail-safe avionics and ultra-reliable engines, substantially increasing light-plane safety and affordability.

A second partnership, initiated in 1996, is uniting propulsion manufacturers, airframe makers, other industries, and government to develop and demonstrate new propulsion systems that are significantly more reliable, maintainable, and affordable. Future piston engines will cost approximately 50 percent less than today's engines, and next-generation turbofan-powered aircraft will fly 100 mph faster than today's light planes.

- Enabling Technology Goal: Invigorate the general aviation industry, delivering 10,000 aircraft annually within 10 years, and 20,000 aircraft annually within 20 years.

Next-Generation Design Tools and Experimental Aircraft

This area of revolutionary advancement will dramatically affect the way we do business. Its impact will be felt across the three pillars, contributing to every technology goal.

Experimental aircraft are invaluable tools for exploring new concepts and for complementing and strengthening laboratory research. In the very demanding environment of flight, "X-planes" are used to test innovative, high-risk concepts, accelerating their development into design and technology applications.

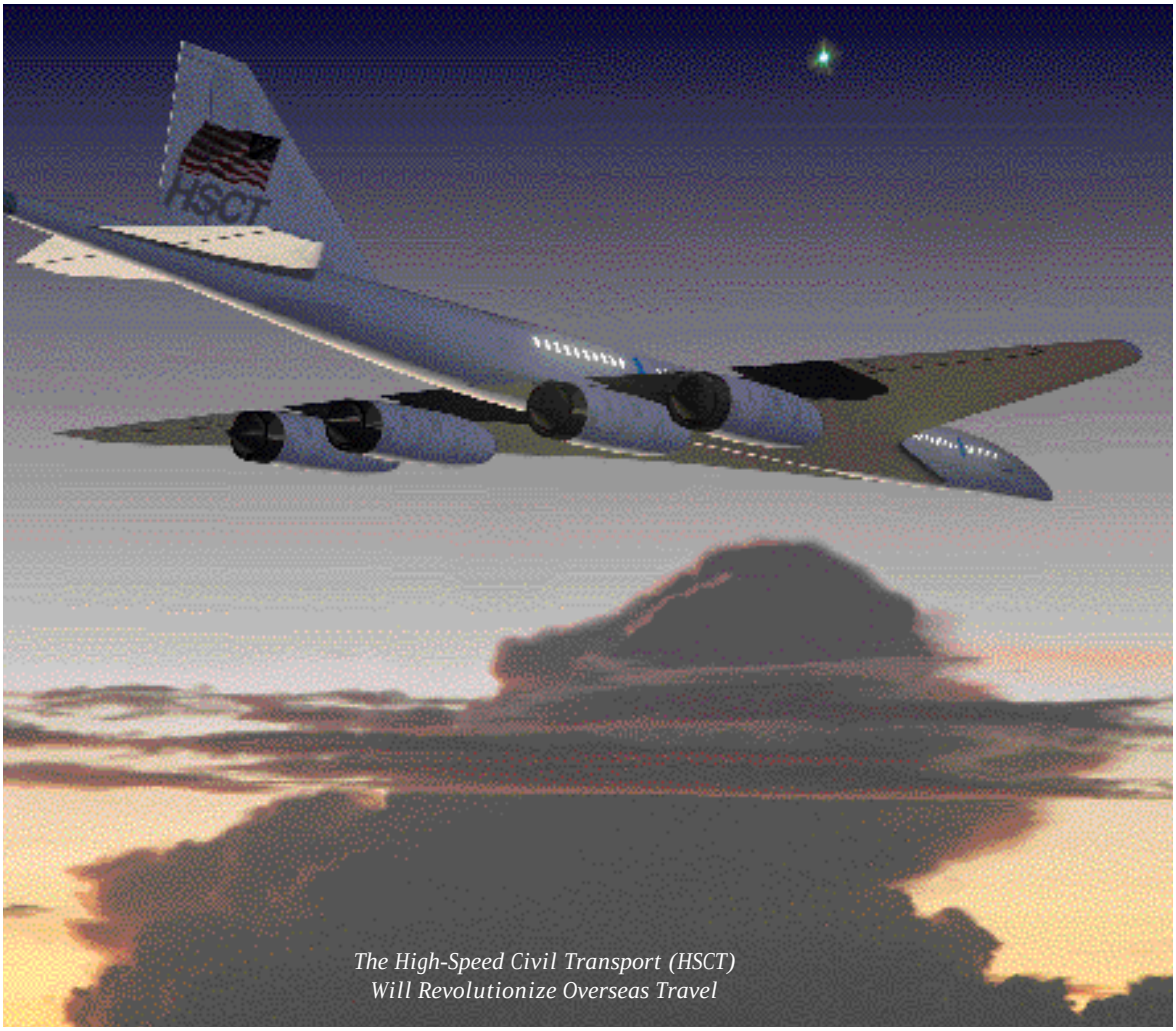
Since World War II, NASA and DOD have conducted literally hundreds of joint flight research programs, most notably the X-planes, but including many other experimental and operational aircraft. NASA intends to increase and improve the use of X-planes as a research tool to further reduce technology development schedules and cost. The NASA and DOD partnership on the X-36 is an example of this approach. The X-36 is a tailless subscale experimental aircraft that will dramatically change the design of future stealth fighters. Its revolutionary design was built at a fraction of the cost and schedule typical of other X-aircraft.

NASA has initiated the Hyper-X program to validate hypersonic air-breathing vehicle and engine design methods in flight. Hyper-X will demonstrate hydrogen-fueled, airframe-integrated, dual-mode ramjet and scramjet propulsion, with flight tests at 5, 7, and 10 times the speed of sound. This technology will have application in both aviation and space access systems.

The pioneering spirit at work in the X-1 and X-15 projects is being recaptured through the renewed emphasis of X-planes. The breakthrough work accomplished by these projects will move our country forward with an improved base of technical knowledge.

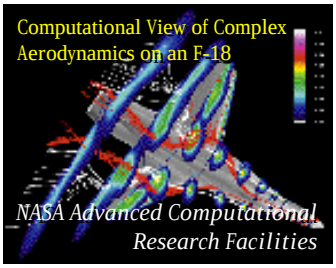
In addition to the tools of flight, next-generation design tools will revolutionize the aviation industry. Design was once solely applying lead to paper. Research in information technology will elevate the power of computing tools through fuzzy logic and artificial intelligence. These tools will integrate multidisciplinary product teams, linking design, operations, and training databases to dramatically cut design cycle times.

- Enabling Technology Goal: Provide next-generation design tools and experimental aircraft to increase design confidence, and cut the development cycle time for aircraft in half.



The High-Speed Civil Transport (HSCT)
Will Revolutionize Overseas Travel

Advanced Design for
General Aviation Aircraft



Computational View of Complex
Aerodynamics on an F-18

NASA Advanced Computational
Research Facilities

Hyper-X:
Airbreathing Propulsion
Research to Mach 10

X-36
Tailless
Stealth
Fighter Prototype

The Reusable Launch Vehicle (RLV) initiative is a partnership for space launch leadership of NASA and private industry and represents a new way of doing business.

The Promise of Low-Cost Space Access

In coming decades, NASA envisions the space frontier as a busy crossroads of U.S.-led international science, research, commerce, and exploration. Our experience with this vast resource has already yielded new treasures of scientific knowledge, life-enhancing applications for use on Earth, and fantastic celestial discoveries. The potential for the future seems almost limitless.

The Challenge

Without affordable and reliable access to space, the future of the space program is hindered by the high cost, low reliability, and poor operability of payload launch. The United States, as well as the rest of world, is struggling with this situation today. The cost of space access is roughly $10,000 per pound of payload delivered to low-Earth orbit. The growth of an otherwise dynamic, creative, and productive U.S. space enterprise is severely impeded by this daunting price tag.

Government space access needs are only a part of the growing U.S. space enterprise. Corporate and university-sponsored research, space business development, in-space manufacturing for pharmaceutical and electronic products, and the U.S. space transportation industry are all impacted by the current costs.

In the last 25 years, the U.S. has developed one major launch vehicle and rocket engine. In the same time frame, other nations have developed 27 rocket engines and many more launch vehicles. Our launchers, once preeminent, now supply only 30 percent of the worldwide commercial market. In the world's rapidly expanding launch business, the U.S. continues to lose market share.

To realize the potential for research and commerce in space, America must achieve one imperative, overarching goal—affordable access to space. The space transportation industry can benefit significantly from the transfer of aviation technologies and flight operations to launch vehicles. High reliability and rapid turn-around are the first steps to increased confidence in delivering payloads on time with fewer ground crew.

- Enabling Technology Goal*:* Reduce the payload cost to low-Earth orbit by an order of magnitude, from $10,000 to $1,000 per pound, within 10 years.

Revolutionizing America's Space Launch Capabilities

NASA, in an unprecedented partnership with aerospace companies, is working to maximize the respective strengths of government and the aerospace industry. NASA's primary space transportation technology role is to develop and demonstrate pre-competitive, next-generation technology that will enable the commercial launch industry to develop full-scale, highly competitive, and reliable space launchers.

Reusable Launch Vehicles (RLV)

NASA's RLV effort includes ground-based technology development and a series of flight demonstrators: the Clipper Graham, the X-34 air-launched flight demonstrator, the X-33 advanced technology demonstrator, and future experimental vehicles.

The Clipper Graham flight tested the first-ever large-scale composite hydrogen tank, a new lightweight aluminum-lithium oxygen tank, and composite fuel lines, joints, and valves. Flying in late 1998, the X-34 will test improvements made through knowledge gained from the Clipper Graham and additional advanced technologies associated with reusable launchers. The air-launched X-34 focuses on the flight regime up to Mach 8.

A major decision point was reached in the summer of 1996 to proceed with building the X-33 flight demonstrator. This suborbital prototype for a single-stage-to-orbit vehicle will feature vertical takeoff and glider-like landings using its lifting-body shape. It will be pilotless, using autonomous controls for operation, but capable of testing all critical systems in a realistic flight environment. It is scheduled to begin flight tests in March 1999, and will demonstrate reliability through frequent flights. The objective is to achieve a reliability of 0.999 with turn-around measured in days, not weeks.

Far-Term Space Transportation Technology

NASA has also initiated research on a broader spectrum of long-term technology advancements that have the potential to reduce costs well beyond the RLV goals. It involves new technologies and integrating aeronautical principles such as air-breathing propulsion and advanced structures. This will enable a cost to orbit measured in hundreds, not thousands, of dollars per pound.

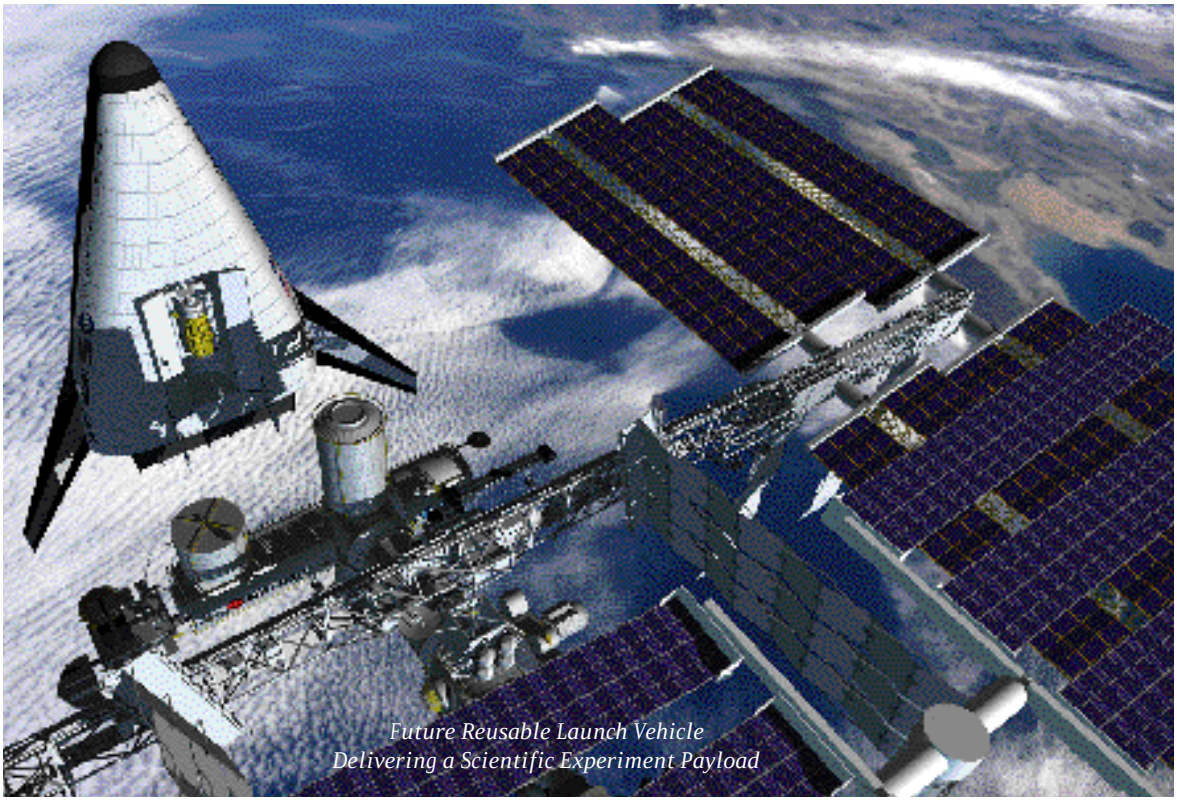
Advanced research and development efforts will address a recognized need for order-of-magnitude cost reductions in three key technology areas: (1) advanced reusable propulsion technology for future commercial RLVs and beyond; (2) small payload launch technology for small businesses and academic research; and (3) advanced space transfer technology for placing satellites into high-Earth and geostationary orbits.

- Enabling Technology Goal*:* Reduce the payload cost to low-Earth orbit by an additional order of magnitude, from $1,000's to $100's per pound, by 2020.

Winning the Revolution in Space Access

America can, and must, achieve radical reductions in the cost of access to space. We can do it in years, not decades, and we must begin now if we are to succeed in realizing the benefits that leadership in this endeavor will bring. We must also achieve our goals without sacrificing safety and reliability. When successful, we will open the doors to space commerce, enable exploration-class missions, and protect our national security.

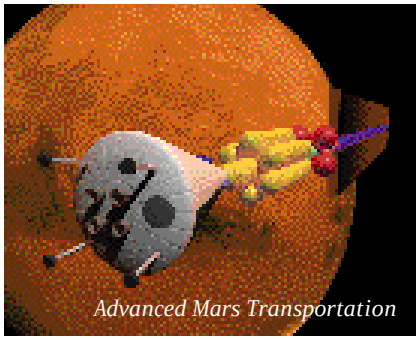
Entrepreneurs, scientists, students, explorers, and many others will be active participants in an exciting era of space development.



Future Reusable Launch Vehicle
Delivering a Scientific Experiment Payload

Advanced Propulsion Research Vehicle
to Revolutionize Space Access

Magnetohydrodynamic
Drive Research



Advanced Mars Transportation

X-34 Air Launch Research Vehicle

Summary

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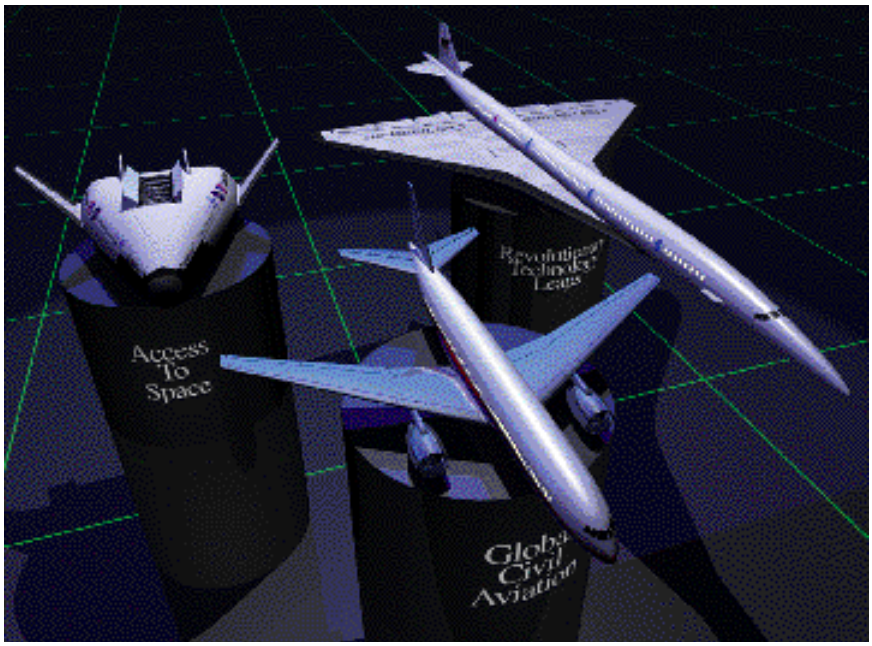
The Presidential reports on aeronautics and the revised "National Space Policy" (1996) outline U.S. policies and actions needed for continued leadership in aeronautics and space. Providing revolutionary new tools and technology advancements is NASA's response to our Nation's needs. The technology goals within the three pillars were developed in collaboration with our industry partners, the Department of Defense, the Federal Aviation Administration, and academia.

Achieving our goals lays a foundation for immeasurable opportunities for the United States. The Nation's investment in NASA will be returned many times over through enabling technologies for a safer, cleaner, and more affordable global aviation system; for sustainable growth in aviation products and services; and for affordable access to space.

Our agenda for action has already begun through the definition of goals for our "Three Pillars." We are now working with our partners in FAA, DOD, industry, and academia to refine the research plans that will lead to the achievement of our final goals.

Many of NASA's programs in aeronautics and space transportation technology are already positioned to address these goals, although some changes to our programs are required. One key example is NASA's plan to intensify efforts in aviation safety research in response to the recommendations of the White House Commission on Aviation Safety and Security.

NASA has set its sights for the future. The goals in our Three Pillars are bold and they are measurable. With the expertise of our workforce, our unique research facilities, and our strong partnerships, our goals are achievable.



"NASA's support of basic, fundamental aeronautics research helped establish America as the world's leader in this field. As a result, one can now travel around the globe more safely, quickly, and at less cost than ever before. It is absolutely critical that we continue to support this important NASA program."

The Honorable John Glenn
United States Senator

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We look forward to your feedback.

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